The PHENIX Time Expansion Chamber

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The TEC/TRD subsystem will track all charged particles and contribute to the particle identification by the measurement of energy loss. The design, construction and testing of the TEC chambers are described.

1. Introduction

The primary goal of the PHENIX collaboration is the detection and characterization of the quark-gluon plasma through the detection of photons, hadrons, and lepton pairs[1]. The PHENIX detector is designed as a high rate detector covering a selective acceptance. Multiple detector technologies are used to achieve very discriminating particle identification. The Time Expansion Chambers (TEC) provides tracking information and contributes to the electron-pion discrimination by dE/dx measurements of the charged particles passing through it. The main functions of the PHENIX Time Expansion Chamber (TEC) are: (1) to track all charged particles passing through the region between the ring-imaging Cherenkov detector (RICH) and the electromagnetic calorimeter (EMCal), (2) to determine particle species using dE/dx information, and (3) to provide a high resolution momentum measurement for high p_t particles. The TEC has the ability to efficiently track charged particles in extremely high multiplicity environments. The mechanical structure and the electronics design allows for a planned future upgrade from a TEC to a Transition Radiation Detector (TRD) with the addition of radiator foils.

2. Detector Design

The Time Expansion chamber is located in the East Arm of the PHENIX detector, in between the Ring Imaging Cherenkov detector (RICH) and the Electromagnetic Calorimeter (EMCAL) as shown in Figure 1. The detector consists of six planes of wire chambers built in four flat 22.5° sectors. The TEC occupies the region where the inscribed radius from the vertex is between 4.1 m and 5.0 m and has an active area that covers $\eta = \pm 0.35$

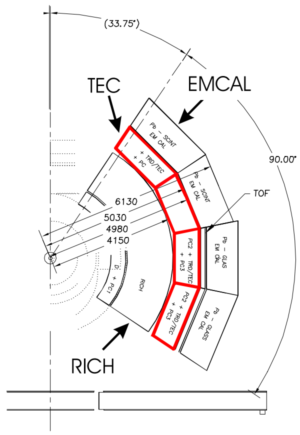

Figure 1. Layout of the East Central Arm in the PHENIX experiment.

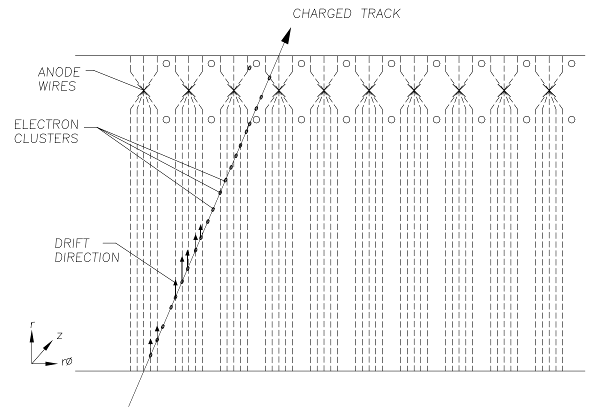

Figure 2. Schematic of Time Expansion Chamber showing anode/cathode configuration, electric field lines and a charged track traversing the TEC.

and $\phi = \pi/2$. Each wire chamber contains a Cu-mylar window followed by a 3-cm drift space, a plane of cathode wires, a plane of 25-μm Au-W anode wires, a second plane of cathode wires and a final Cu-mylar window as shown in Figure 2. The anode wires are spaced 4 mm from each other and 3 mm from the cathode wire planes. Each anode wire is divided in z at a thin G-10 wire support structure running across the midpoint of each frame. The detector frames, made from a combination of G-10, S2 glass and carbon composite material, allow a frame design that maintains rigidity under wire tension loading but has a minimum amount of material in the active region. The anode and cathode wires run to the edge of the detector frame where they are glued to the frame with epoxy and electrically connected to printed circuit boards laminated to the frames. When charged tracks pass through the chamber, electrons are liberated in the gas and drift toward the anode wires, guided by the field gradients maintained in the chamber. Electron clusters that reach the anode are multiplied by the proportional wire chamber avalanche process and the resulting signal is routed through traces on the TEC's printed circuit boards to the preamplifier electronics.

3. Readout

The TEC electronics chain comprises a preamplifier, a unipolar shaping amplifier with 70 ns integration time, a 5-bit non-linear flash ADC designed to run at 36 MHz (i.e., one quarter of the time between RHIC crossings), a digital memory chip, digital data formatting and an optical transmitter. The parameters of the electronics chain are de-

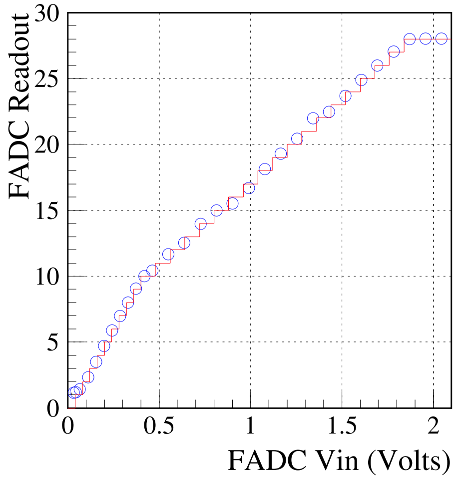

Figure 3. FADC response to input test signal.

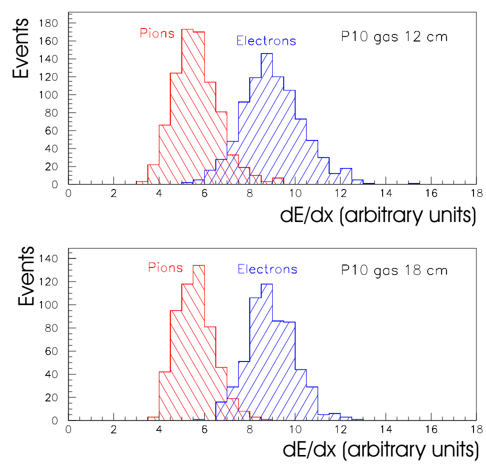

Figure 4. Energy deposited in the TEC by the electron and pion beams with 50% truncation level[4].

termined by requirements of both the TEC dE/dx and the TRD operation. The 70 ns shaping is chosen so that the FADC clock runs at a fraction of the shaping time to assure good position resolution and smoothing of energy loss signals. The shaping amplifier has a dual output with an additional gain stage (X5 and X25 gain) on one of the output lines for increased dynamic range. Both lines feed into the FADC. The BNL-designed preamplifier/shaping amplifier contains eight channels/chip and is manufactured with the Hewlett Packard 1.2 μm n-well CMOS process[2]. The shaping function is unipolar, with a semi-Gaussian impulse response, 70 ns peaking time and a FWHM < 100 ns. The ENC is less than 1500 electrons. The 5-bit non-linear FADC chip is also BNL-designed and is produced in the 1.2-μm CMOS process at ORBIT. The design sets the 31 comparator levels, which are 28 in the low dE/dx range and three in the high TRD range covering a total of 8-bit dynamic range. The 28 lower levels are set in a nonlinear distribution to respond to charge signals of 2–120 fC on the input of the preamp, as shown in Figure 3.

4. Detector Performance

The TEC Particle Identification capability was evaluated with an in-beam test at the AGS. Electrons and pions in the beam were tagged by a gas Cherenkov counter and a Lead Glass detector. The TEC chamber was continuously flushed with P10 gas and was operated with a gas gain of about 10^4. Since dE/dX distribution in thin media has a very long tail at very large energy losses, truncation of largest dE/dX samples is used to improve energy resolution. Optimal truncation levels were found to be 50%-70%. Figure 4 shows the distribution of energy loss for 0.5 GeV/c electrons and pions using 4 and 6 TEC planes. For 90% electron reconstruction efficiency, the probability of misidentifying pions was found to be 5% and 1% respectively. A pattern recognition algorithm based on Combinatorial Hough Transforms, was used to reconstruct particle

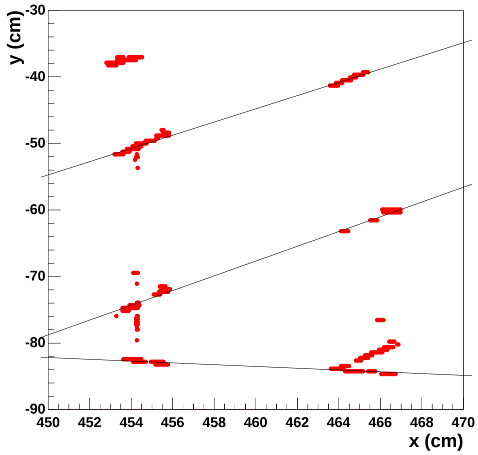

Figure 5. Beam loss event taken with 2 planes of TEC in PHENIX Engineering Run with one RHIC Ring Operating

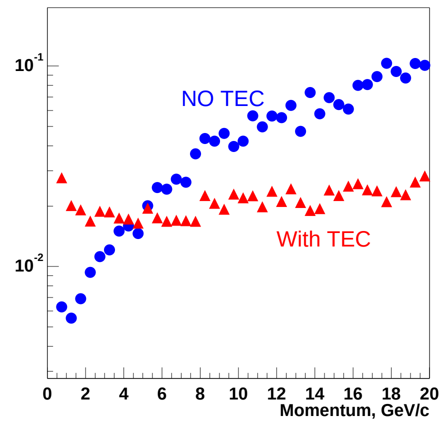

Figure 6. Estimated Momentum Resolution $[\sigma_P/P(\%)]$ with and without the Time Expansion Chamber.

trajectories in the TEC, as shown in Figure 5 for a typical beam loss event taken during the PHENIX Engineering Run when one RHIC Ring was operating. A Monte Carlo program was developed to estimate the detector performance in a high multiplicity environment. The TEC simulator reproduces in minute details physical processes occurring in TEC while a charged particle passes through it. Both primary and secondary ionization are taken into account. Gas gain fluctuations, charge drift through the TEC volume and electronics response are reproduced[3]. The simulation studies showed that combining the TEC tracking information to the drift chamber tracks greatly improves the momentum resolution for particles with momenta >3 GeV/c as shown in Figure 6. Tracking efficiency was studied for a variety of track density condition and was shown to be >95% even at double the expected track density for Au-Au collisions.

5. Acknowledgments

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